Research article

Clinical interpretation of the Spinal Cord Injury Functional Index (SCI-FI)

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Objective: To provide validation of functional ability levels for the Spinal Cord Injury – Functional Index (SCI-FI).
Design: Cross-sectional.
Setting: Inpatient rehabilitation hospital and community settings.
Participants: A sample of 855 individuals with traumatic spinal cord injury enrolled in 6 rehabilitation centers participating in the National Spinal Cord Injury Model Systems Network.
Interventions: Not Applicable.
Main Outcome Measures: Spinal Cord Injury-Functional Index (SCI-FI).
Results: Cluster analyses identified three distinct groups that represent low, mid-range and high SCI-FI functional ability levels. Comparison of clusters on personal and other injury characteristics suggested some significant differences between groups.
Conclusions: These results strongly support the use of SCI-FI functional ability levels to document the perceived functional abilities of persons with SCI. Results of the cluster analysis suggest that the SCI-FI functional ability levels capture function by injury characteristics. Clinical implications regarding tracking functional activity trajectories during follow-up visits are discussed.

Keywords: Cluster analysis, Spinal cord injuries, Motor activities, Activities of daily living

A growing number of patient reported outcome measures (PROs) are being used in spinal cord injury (SCI) medicine as standard metrics of functional outcomes for quality improvement and reimbursement.[1–4] However, current measures used to assess functional status in SCI medicine have well-established measurement limitations. For example, the Functional Independence Measure (FIM™), a commonly used measure of functional outcomes in rehabilitation does not assess the breadth of functional abilities of all persons with SCI.[5,6] The FIM™ motor scores have been found to lack sensitivity in the differentiation of functioning for persons with thoracic and cervical SCI,[5] lack sensitivity to detect change in scores due to substantial ceiling effects,[6] and were in fact removed from the 2000 revisions of the International Standards for Neurological Classification of Spinal Cord Injury.[7]

The Spinal Cord Injury-Functional Index (SCI-FI) is a new series of PRO measures of physical functioning, specifically developed for persons with SCI. The SCI-FI was designed using item response theory (IRT) and computerized adaptive testing (CAT) to overcome many of the measurement challenges found in current functional measures used the SCI population.[8–11] SCI-FI items were generated based on focus group discussions with persons living with SCI and SCI rehabilitation specialists to ensure that items assessed key functional activities that are important to individuals with SCI[9–11] and consistent with common data elements found in other scales (PROMIS, Neuro-QOL).[8,9] The

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SCI-FI can be administered via computer or touch screen tablet using CAT or short forms to assess five functional domains: basic mobility, self-care, fine motor function, ambulation and wheelchair mobility.[8,11,12] CAT administration selects SCI-FI items for each individual based on their responses to previous items. In this manner a few well-selected items yield a SCI-FI score that provides a precise estimate of a person's ability in each domain. These technological advances used in administration of the SCI-FI facilitate prompt data collection of functional status information and reduces the burden on clinical staff that may be experienced in the data entry and scoring of paper forms.[13]

Since it may be difficult for patients and clinicians to interpret the significance of standardized SCI-FI scores,[4] functional ability levels were established for each SCI-FI domain,[9,14] to provide clinicians with meaningful cut-off scores that distinguish the functional abilities of persons with SCI across the five SCI-FI domains. For example, a SCI-FI Basic Mobility standardized score of 40 corresponds to functional ability level of 2 (out of 5 levels). An SCI patient with a SCI-FI Basic Mobility functional ability level of 2 endorses that s/he is able to do "activities involving upright trunk and gross upper extremity movement." In contrast, another SCI patient may report a SCI-FI Basic Mobility score of 55 corresponds to a functional ability level of 3 which is characterized by the ability to do "activities involving unsupported sitting, reaching and level transfers." SCI-FI functional ability levels were developed using the original item calibration sample (N = 855) and validated in another sample (N = 269).[9,12,15] While these initial results are encouraging, further study is needed to determine if the established number of levels and cut points are optimal for use by clinicians.[14]

The current study was designed to build on prior psychometric validation of the SCI-FI functional ability levels to examine the association between neurological level and extent of the lesion on SCI-FI functional ability levels.[16,17] We used cluster analysis to determine clinically meaningful group profiles based on their SCI-FI functional ability levels across the SCI-FI domains. Identifying clusters of cases with SCI injury characteristics (e.g. injury severity) that are reliably associated with different SCI-FI functional ability levels can lend support to the SCI-FI as a clinically useful PRO of an SCI patients' evaluation of their functional status. Thus, this study aims to use cluster analysis to provide additional validation to support the overall structure of the SCI-FI functional ability levels associated with different SCI injury characteristics.

Methods

We used data from the SCI-FI calibration study and the functional ability level development studies to conduct the cluster analysis. These studies were approved by the Institutional Review Board of collaborating institutions.[9,11,14]

SCI-FI development study

The SCI-FI items were developed based on functional activities that were identified by patient and clinician focus groups and items were categorized using International Classification of Functioning Disability (ICF) conceptual framework to measure the concept of activity limitation.[10] A sample of 855 persons with traumatic spinal cord injury was recruited for the SCI-FI calibration study and data were collected across six centers during the 2006–2011 grant cycle of the Spinal Cord Injury Model System (SCIMS). Factor analysis revealed five distinct unidimensional domains and IRT analyses were conducted to create calibrated item banks comprised of items scaled along a continuum of difficulty. The SCI-FI calibrated item banks include: basic mobility (54 items), self-care (90 items), fine motor function (36 items), ambulation (39 items) and wheelchair mobility (56 items).[9,11] The SCI-FI item banks demonstrated adequate psychometric properties.[9,11,15] Each SCI-FI item bank can be administered as a CAT to maximize measurement precision while significantly reducing participant burden[11] or as a static short form consisting of a fixed number of carefully selected items.[15] SCI-FI items assess an individual's underlying capacity to perform functional activities by using 5 response options to describe the amount of difficulty the person has doing an activity (i.e. 5 = without any difficulty to 1 = unable to do to). A subset of SCI-FI items (3 Basic Mobility items, 1 Fine Motor item and 3 Self-Care items) use 4 response options that describe the amount of help from another person needed to perform an activity (i.e. 4 = none to 1 = total). For each item, SCI-FI respondents are instructed to indicate the amount of difficulty they have doing the activity without any devices, special equipment, or help from another person.[11] SCI-FI raw scores are then standardized and transformed to the T metric, with a mean of 50 and standard deviation (SD) of 10.[9,11] Higher SCI-FI scores indicate greater perceived functional ability.[9,11]

Development of the SCI-FI functional ability levels

Modified bookmarking methods were used to establish clinically meaningful functional ability levels for SCI-FI scores to identify cut-off scores to classify important differences in functional abilities for each of the five

domains.[14] Bookmarking utilizes items maps that are developed from the IRT analyses of item banks to display the pattern of item responses for items that are hierarchically organized based on item difficulty (logit score).[18,19] An expert panel of rehabilitation specialists reviewed the item maps to reach consensus about the scores that discriminated among different levels of functional ability to identify the appropriate number of levels and meaningful cut-off scores. This process was repeated for each domain and the functional levels were examined in two samples.[14] Further examination of the SCI-FI functional ability levels is warranted to determine if the number of functional levels and cut-off scores determined by expert consensus are optimal.

Cluster analyses

Cluster analyses were run to identify clusters of individuals where the groupings were not pre-determined and to sort cases (or variables) into a small number of groups such that members in the same group were as similar as possible, while members of different groups were as dissimilar as possible on a specific metric.[20] Prior to clustering, the distributions of functional ability levels for each of the five SCI-FI domains were examined using histograms. The ambulation domain was significantly skewed as most respondents were not ambulatory and this domain was excluded from the cluster analysis. The remaining domains (i.e. basic mobility, self-care, fine motor function and wheelchair mobility) exhibited normal distributions. A two-step clustering algorithm was used to perform the cluster analysis.[21] First, a sequential clustering approach was used by constructing a modified cluster feature tree. Next, sub-clusters that result from the pre-clustering stage were grouped using hierarchical clustering methods. Finally, the number of clusters were automatically selected based on Bayesian Information Criterion (BIC) values.

Validity of the clusters was examined using both qualitative and quantitative methods. We hypothesized there would be significant cluster differences across SCI injury characteristics because physical function, as measured by the SCI-FI domains, is closely linked to level and severity of injury (i.e. AIS grade). Other characteristics, such as time since injury and age, were also examined since these characteristics are likely to have some relationship with cluster membership although to a less robust extent than injury level. Demographics, such as race/ethnicity or sex, were not hypothesized to have a relationship with clustering. To provide quantitative support for the validity of clusters, we utilized one-way ANOVAs with Bonferroni correction and Pearson χ^2 analysis to compare continuous and categorical variables, respectively, by clusters. Cramer's V was used to estimate effect size of relationships of categorical variables; values range from 0.0 (total independence) to 1.0 (total dependence). For Pearson Chi-square analyses, a standardized residual (SR) value (a z-score) ≥ 2.0 was used to identify a statistically significant difference between expected and observed cases; negative SR values indicate under-representation and positive SR values indicate over-representation in a sub-sample. IBM SPSS™ version 22 (IBM Corp., Armonk, NY, USA) was used for all analyses.

Results

Description of SCI-FI calibration sample

The majority of SCI-FI participants were persons who self-identified as White (72.9%), male (78.9%), injured as a result of a motor vehicle accident (35.1%) and living at home (77.8%).[11] Additional demographic and clinical characteristics of the SCI-FI calibration study sample are representative of the national SCIMS database and are detailed elsewhere.[11] Of the original 855 calibration study participants, 148 were removed from the analyses as they did not have complete data for the four SCI-FI domains used in the cluster analysis. Therefore, a sample of 707 participants was included in the cluster analysis. Table 1 presents demographic and injury characteristics of the total sample by cluster group membership.

Cluster analysis profiles of the SCI-FI functional ability levels

Results identified a three-cluster solution based on similarity in the SCI-FI functional ability levels within clusters and variability between clusters. Participants in Cluster 1 (n = 300; 42.4%) were characterized by high functional ability levels, which represents perceived ability to be able to do most SCI-FI activities across domains without any difficulty. Cluster 2 (n = 196; 27.7%) was characterized by participants who reported mid-range functional ability levels which represents perceived ability to complete some SCI-FI activities with some difficulty across domains. In Cluster 3 (n = 211; 29.8%), the majority of participants reported low functional ability levels which represents perceived inability to complete many SCI-FI activities across domains. The distribution of cluster samples within each functional ability level and across SCI-FI domains is shown in Table 2.

The distinction among clusters was confirmed with χ^2 analysis, where all tests for each of the four SCI-FI

Table 1 Demographic and injury characteristics and SCI-FI scores for the total sample and by clusters

	Total Sample (N = 707)	Cluster 1 High Functional Ability (n = 300; 42.4%)	Cluster 2 Mid-Range Functional Ability (n = 196; 27.7%)	Cluster 3 Low Functional Ability (n = 211; 29.8%)	Test, Statistical Sig., and Post Hoc Contrasts*
Characteristic			Mean (SD)		
Age (years)	41.8 (14.8)	41.3 (14.4)	44 (15.2)	40.0 (14.9)	$F = 4.74$, P = 0.009; 2 > 1 and 3
Time since injury (years)	7.2 (9.8)	8.4 (10.2)	7.1 (9.9)	5.4 (8.9)	$F = 6.11$, P = 0.002; 1 > 3
			N (% within cluster)		
Race/ethnicity					
Non-Hispanic White	445 (67.5)	188 (66.2)	125 (69.1)	132 (68.0)	$\chi^2 = 0.523$, P = 0.971, Cramer's V = 0.028
Non-Hispanic Black	125 (19.0)	57 (20.1)	32 (17.7)	36 (18.6)	
Hispanic/Latino	89 (13.5)	39 (13.7)	24 (13.3)	26 (13.4)	
Male	543 (76)	229 (76.3)	147 (75.0)	167 (79.1)	$\chi^2 = 1.04$, P = 0.593, Cramer's V = 0.038
Living at home (vs. rehabilitation facility)	524 (74.1)	260 (86.7)	132 (67.3)	132 (62.6)	$\chi^2 = 44.1$, P < 0.001, Cramer's V = 0.249
Injury Etiology					
Vehicular	242 (34.2%)	96 (32.0)	80 (40.8)	66 (31.3)	$\chi^2 = 68.3$, P ≤ 0.001, Cramer's V = 0.311
Falls	143 (20.2%)	61 (20.3)	41 (20.9)	41 (19.4)	
Violence	87 (12.3%)	54 (18.0)	16 (8.2)	17 (8.1)	
Diving	66 (9.3%)	6 (2.0)	22 (11.2)	38 (18.0)	
Other Sports	26 (3.7%)	8 (2.7)	3 (1.5)	15 (7.1)	
Other	143 (20.2%)	75 (25.0)	34 (17.3)	34 (16.1)	
ASIA					
A	351 (57.7)	139 (57.0)	90 (52.3)	122 (63.5)	$\chi^2 = 16.4$, P = 0.012, Cramer's V = 0.164
B	105 (17.3)	35 (14.3)	36 (20.9)	34 (17.7)	
C	87 (14.3)	40 (16.4)	20 (11.6)	27 (14.1)	
D	65 (10.7)	30 (12.3)	26 (15.1)	9 (4.7)	
Level of Injury					
Tetraplegia	352 (54.8)	37 (14.2)	116 (64.8)	199 (98.5)	$\chi^2 = 337.0$, P ≤ 0.001, Cramer's V = 0.75
Paraplegia	290 (45.2)	224 (85.8)	63 (35.2)	3 (1.5)	
Severity of Injury					
Complete injury	352 (56.6)	134 (55.2)	90 (51.2)	123 (63.1)	$\chi^2 = 5.448$, P = 0.066, Cramer's V = 0.094
Incomplete injury	270 (43.4)	113 (44.8)	85 (48.6)	72 (36.9)	
Neurological Category					
Tetra complete	176 (28.3)	9 (3.6)	45 (25.7)	122 (62.6)	$\chi^2 = 359.4$, P = 0.001, Cramer's V = 0.538
Para complete	176 (28.3)	130 (51.6)	45 (25.7)	1 (0.5)	
Tetra incomplete	164 (26.4)	26 (10.3)	68 (38.9)	70 (35.9)	
Para incomplete	106 (17.0)	87 (34.5)	17 (9.7)	2 (1.0)	
Uses manual wheelchair some or most of the time	434 (61.5)	271 (90.6)	116 (59.2)	47 (22.3)	$\chi^2 = 244.7$, P ≤ 0.001, Cramer's V = 0.589
Uses power wheelchair some or most of the time	356 (50.0)	57 (19.1)	110 (47)	189 (89.6)	$\chi^2 = 0.49.5$, P ≤ 0.001, Cramer's V = 0.595
SCI-FI Domain Scores			Mean (SD)		
Self-care	48.34 (10.49)	57.78 (3.9)	48.19 (2.5)	35.08 (6.1)	F = 1621.71, P = 0.001, 1>2 and 3
Basic mobility	47.63 (9.5)	55.49 (3.9)	47.82 (3.8)	36.29 (7.2)	F = 879.98, P = 0.001, 1>2 and 3
Fine motor	48.84 (10.22)	57.68 (4.3)	49.11 (4.6)	36.02 (5.3)	F = 1299.46, P = 0.001, 1>2 and 3
Wheelchair mobility	49.68 (11.00)	58.67 (5.3)	49.25 (5.4)	37.30 (8.4)	F = 691.43, P = 0.001, 1>2 and 3

domains were statistically significant (all P ≤ 0.001). The two-step cluster analysis also shows the relative importance of the variables in the determination of clusters; the self-care domain was the most important predictor and wheelchair mobility domain was the least important predictor in cluster assignment.

Demographic and injury characteristics by cluster

Cluster membership was not associated with racial/ethnic background, sex, or having a romantic partner. In contrast, there were significant cluster differences by age and time since injury. Participants in Cluster 2

Table 2 Distribution of the cluster samples across functional levels by SCI-FI domains

Domain	Functional Ability Levels (Score Intervals)	Cluster 1 n = 300	Cluster 2 n = 196	Cluster 3 n = 211
Self-care		n (%)	n (%)	n (%)
	1. No self-care activities (SCI-FI score ≤32)	0 (0)	0 (0)	78 (37.0)
	2. Eating and some basic dressing and bathing activities (SCI-FI score 33–43)	0 (0)	8 (4.1)	132 (62.5)
	3. Most basic dressing and bathing activities (SCI-FI score 44–51)	0 (0)	188 (95.9)	1 (0.5)
	4. Most self-care activities (SCI-FI score 52–60)	236 (78.7)	0 (0)	0 (0)
	5. All self-care activities (SCI-FI score ≥61)	64 (21.3)	0 (0)	0 (0)
Basic mobility				
	1. Activities involving limited shoulder, head and supported upper body movement (SCI-FI score ≤ 28)	0 (0)	0 (0)	35 (16.6)
	2. Activities involving upright trunk and gross upper extremity movement (SCI-FI score 29–40)	0 (0)	5 (2.5)	113 (53.5)
	3. Activities using upper extremities while sitting unsupported and some transfer activities (SCI-FI score 41–50)	35 (11.7)	145 (74.0)	62 (29.4)
	4. Activities involving unsupported sitting, reaching and level transfers (SCI-FI score 51–63)	255 (85.0)	46 (23.5)	1 (0.5)
	5. Activities involving unsupported sitting and transfers to/from surfaces of different heights (SCI-FI score ≥64)	10 (3.3)	0 (0)	0 (0)
Fine motor				
	1. No activities requiring hand function (SCI-FI score ≤ 32)	0 (0)	0 (0)	68 (32.2)
	2. Some activities involving gross hand movement (SCI-FI score 33–43)	0 (0)	19 (9.7)	140 (66.4)
	3. Some activities requiring dexterity and coordinated upper extremity movement (SCI-FI score 44–51)	33 (11.0)	125 (63.8)	3 (1.4)
	4. Most activities requiring dexterity and coordinated upper extremity movement (SCI-FI score ≥51)	267 (89.0)	52 (26.5)	0 (0)
Wheelchair mobility				
	1. No wheelchair activities (power and manual) (SCI-FI score ≤ 15)	0 (0)	1 (0.5)	7 (3.3)
	2. Unable to do most wheelchair activities (manual) OR some wheelchair activities (power) (SCI-FI score 16–40)	0 (0)	6 (3.1)	120 (56.9)
	3. Some basic wheelchair activities (manual) OR all wheelchair activities (power) (SCI-FI score 41–52)	38 (12.7)	150 (76.5)	84 (39.8)
	4. Most wheelchair activities (manual) OR no difficulty with any activities (power) (SCI-FI score 53–63)	214 (71.3)	39 (19.9)	0 (0)
	5. All wheelchair activities (manual) OR NA (power) (SCI-FI score ≥ 64)	48 (16.0)	0 (0)	0 (0)

(mid-range functional ability level) were significantly older than participants in Cluster 1 (high functional ability level) and Cluster 3 (low functional ability level; both $P = 0.009$). Time since injury was significantly longer among participants in Cluster 1 than participants Cluster 3 ($P = 0.001$). Using either a manual or power wheelchair some or most of the time was significantly related to cluster membership. Participants in Cluster 1 were most likely to respond "yes" to the using a manual wheelchair (SR = 6.4); whereas, participants in Cluster 3 (SR = 8.0) were most likely to respond "yes" to using a power wheelchair.

Injury etiology was also significantly related to cluster membership. Specifically, participants injured by violence were over-represented in Cluster 1 (SR = 2.8) and under-represented in Cluster 2 (SR = –1.7). Compared to other clusters, Cluster 3 had a significantly high proportion of participants injured by diving (SR = 4.1). A similar pattern of results was observed by level of injury (tetraplegia versus paraplegia), which was also significantly related to cluster membership in expected ways. A significantly higher proportion of participants with paraplegia were in Cluster 1 (SR = 9.8) and significantly lower were in Clusters 2 (SR = –2.0) and 3 (SR = –9.2). Participants with tetraplegia were over-represented in Cluster 3 (SR = 8.4) and under-represented in Cluster 1 (SR = –8.9). Since the level and completeness of lesion are strongly associated with functional outcomes, we also compared the cluster group membership by neurological category: complete tetraplegia; incomplete tetraplegia; complete paraplegia; and incomplete paraplegia. A significantly high proportion of participants with complete tetraplegia were in Cluster 3 (SR = 9.0) and incomplete tetraplegia were in Cluster 2 (SR = 3.2); while a significantly high proportion of participants with complete paraplegia (SR = 7.0) and incomplete paraplegia (SR = 6.7) were in Cluster 1.

Although the analytic sample included 608 cases with confirmed AIS grade, significant differences were also

Table 3a Clusters by AIS grade based on injury level

	Tetraplegia (n = 333)			Paraplegia (n = 275)		
	Cluster 1 High Functional Ability (n = 34) n (%)	Cluster 2 Mid-range Functional Ability (n = 110) n (%)	Cluster 3 Low Functional Ability (n = 189) n (%)	Cluster 1 High Functional Ability (n = 210) n (%)	Cluster 2 Mid-range Functional Ability (n = 62) n (%)	Cluster 3 Low Functional Ability (n = 3) n (%)
AIS Grade						
A	9 (26.5)	45 (40.9)	121 (64.0)	130 (61.9)	45 (72.6)	1 (33.3)
B	6 (17.6)	28 (25.5)	33 (17.5)	29 (13.8)	8 (12.9)	1 (33.3)
C	8 (23.5)	17 (15.5)	27 (14.3)	32 (15.2)	3 (4.8)	0 (0.0)
D	11 (32.4)	20 (18.2)	8 (4.2)	19 (9.0)	6 (9.7)	1 (33.3)

Based on n = 608 with complete AIS grade data.

Table 3b Clusters by AIS grade based on injury severity

	Complete Injury (n = 351)			Incomplete Injury (n = 257)		
	Cluster 1 High Functional Ability (n = 139) Wn (%)	Cluster 2 Mid-range Functional Ability (n = 90) n (%)	Cluster 3 Low Functional Ability (n = 122) n (%)	Cluster 1 High Functional Ability (n = 105) n (%)	Cluster 2 Mid-range Functional Ability (n = 82) n (%)	Cluster 3 Low Functional Ability (n = 70) n (%)
AIS Grade						
A	139 (100.0)	90 (100.0)	122 (100.0)	-	-	-
B	-	-	-	35 (33.3)	36 (43.9)	34 (48.6)
C	-	-	-	40 (38.1)	20 (24.4)	27 (38.6)
D	-	-	-	30 (28.6)	26 (31.7)	9 (12.9)

Based on n = 608 with complete AIS grade data.

observed in cluster membership by AIS grade. Specifically, AIS D scores were over-represented in Cluster 2 (SR = 1.8) and under-represented in Cluster 3 (SR = –2.5). Variation was observed in the proportion of individuals across clusters by AIS grade based on injury level (i.e. paraplegia/tetraplegia) (Table 3a) or severity (i.e. complete/incomplete injury) (Table 3b). Among participants with tetraplegia, participants in Cluster 3 were more likely to be AIS A (SR = 2.2); whereas, participants in Cluster 1 were more likely to be AIS D (SR = 3.5), compared to the other clusters. Among participants with paraplegia, the majority of participants across AIS grades were in Cluster 1.

Discussion

SCI-FI functional ability levels provide clinicians and patients with score ranges that distinguish important functional abilities and assign clinical meaning to SCI-FI scores. The purpose of the current study was to use cluster analysis to further validate the SCI-FI functional ability levels. Three distinct clusters of SCI-FI functional ability level scores were identified: Cluster 1 included participants with high SCI-FI functional ability levels (i.e. perceived themselves able to complete most or all activities); Cluster 2 included participants with mid-range SCI-FI functional ability levels (i.e. perceived themselves able to complete some activities); Cluster 3 included participants with low SCI-FI functional ability levels (i.e. perceived themselves able to complete few or unable to complete activities). The self-care domain had the largest influence on cluster assignment, which may reflect the importance of self-care in rehabilitation and the fact that self-care activities (e.g. bathing, toileting) often require a combination of basic mobility and fine motor function. Members in each of the three SCI-FI clusters are similar in terms of their level and extent of SCI, providing further validation of the SCI-FI functional ability levels.

The relationships between cluster membership and injury characteristics of the sample were generally in expected directions. Cluster 1, high functional ability levels, was the largest group. Most of the participants in Cluster 1 were paraplegia AIS A, injured due to violence and had greater use of a manual wheelchair in comparison to the other clusters. Clinically, this finding seems reasonable to observe groups of individuals who were injured due to acts of violence and paraplegia in the same cluster. Participants in Cluster 2 (average functional ability levels) were relatively older, with cervical incomplete injuries and the highest

proportion of participants injured via motor vehicular accidents. Most of the participants in Cluster 3 (low functional ability levels) were newly injured, living with cervical complete injuries and most likely to use a power wheelchair some or most of the time. Clinically, this finding also seems reasonable to observe groups of individuals who were injured due to diving accidents and tetraplegia in the same cluster. Personal characteristics, such as race/ethnicity or sex were distributed equally across clusters. The finding that key injury characteristics are related to the SCI-FI Functional ability levels is consistent with findings that functional ability levels were related to SCI level and severity.[14]

Potential clinical utility

Researchers, clinicians and patients and their families recognize the importance of including PROs as a component of medical rehabilitation assessments.[1] The ability to provide a clinical context for interpreting scores is critical to fully realize the potential of PROs in this population.[4] The SCI-FI can be administered in inpatient and outpatient settings, prior to rehabilitative care visits using a web-based application on a tablet PC with touchscreen and can provide clinicians with assessment results that can be used alongside more traditional clinical information to facilitate patient-provider communication. The five SCI-FI domains administered via CATs or short forms can take patients approximately 10 to 15 minutes to complete while they are in the waiting room. SCI-FI is a psychometrically sound measure of functional activity limitations that is conceptually grounded to efficiently assess a range of activities for all persons with SCI, regardless of AIS grade and level of lesion.[10,11] Unlike existing measures (e.g. FIM) that assess physiological body structure (e.g. bowel/bladder sphincter control), the SCI-FI assesses functional components of bowel and bladder management in the self-care domain (e.g. ability to insert a catheter). While the fine motor domain may be useful in the assessment of upper motor extremity among patients with tetraplegia; the ambulation and wheelchair domains can assess mobility across different surfaces and modalities in patients with incomplete injuries.[11]

Cluster membership can provide information that is similar to the functional ability levels which can be used by clinicians as they identify patterns of functional ability on the basis of injury characteristics at key timepoints in rehabilitation. For example, administering the SCI-FI while a patient with SCI is waiting for his/her first outpatient visit can provide both the patient and clinician with a baseline assessment of functional ability levels that might have occurred since discharge and can be used to discuss goals during the clinical encounter. Using SCI-FI functional ability levels, clinicians can determine whether their SCI patients have a consistent pattern of functional ability that corresponds with their injury characteristics. An example is a patient with chronic incomplete paraplegia who consistently reports his high functional ability levels (Cluster 1) across SCI-FI domain, but on his latest outpatient visit presents with SCI-FI functional ability levels in Cluster 2 (mid-range functional ability level). Such a remarkable change in SCI-FI functional ability levels provides an opportunity for an SCI clinician to discuss the inconsistent pattern of SCI-FI functional ability levels across domains (e.g. change from high basic mobility SCI-FI functional ability level to low functional ability level), identify and act upon problems reported by patients as soon as they occur.

Cluster analyses have been found to be a helpful approach to identify groups of similar people; however, there is no clear and agreed upon method for using this approach and a degree of subjectivity is inherent in the qualitative review of results. Accordingly, the final clusters of functional ability levels should be validated in different samples of individuals with traumatic SCI. Since the distribution of participants within functional ability levels for clusters across domains show that the higher and lower functional levels cluster consistently with more spread in average functional ability levels, replication studies should determine whether collapsing functional ability levels is also warranted. For instance, domains with 5 functional ability levels may be less clinically meaningful for distinguishing between individuals with SCI who are able to complete all and most activities in a domain, so collapsing these functional ability levels may be useful.

Conclusions

These findings provide further validation for the derivation of SCI-FI functional ability levels that are based on patient's self-reported perceived ability to complete functional activities, SCI-FI profile scores can be used to facilitate discussions in clinical encounters, and develop targeted interventions that support the maintenance of independence and optimize SCI patient outcomes. Future replication of these findings provide additional support for the SCI-FI functional levels and provide additional clinical practice recommendations that can evaluate change in a patients' SCI scores across SCI-FI domains over time.

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Conflicts of interest

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